Water cycle extremes in the Mediterranean in a context of climate change

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GEOSCIENCE INFORMATION FOR TEACHERS (GIFT) WORKSHOP

Two reasons to investigate the Mediterranean water cycle...

Critical water resources and droughts

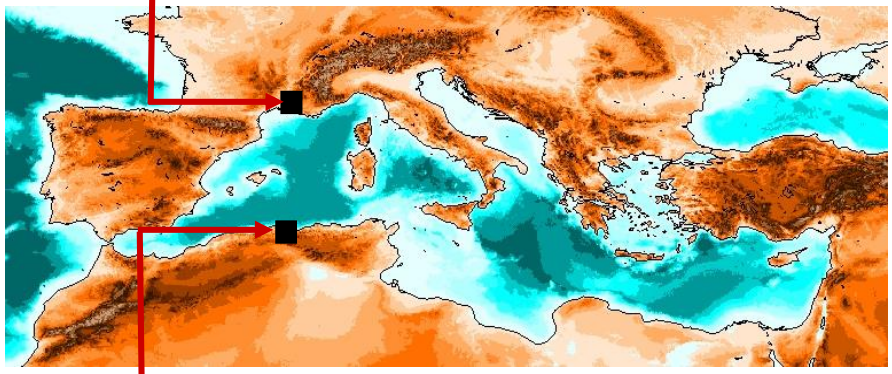
Water resource exploitation index in 2000

- *Demand multiplied by 2 since 1950*
- *60 million inhabitants lacking water*
- *20 million inhabitants without access to drinkable water*

Heavy precipitation and floods

Between1990 and 2006
- more than 175 flood events
- more than 29 140 M€ damages and 4 500 deaths

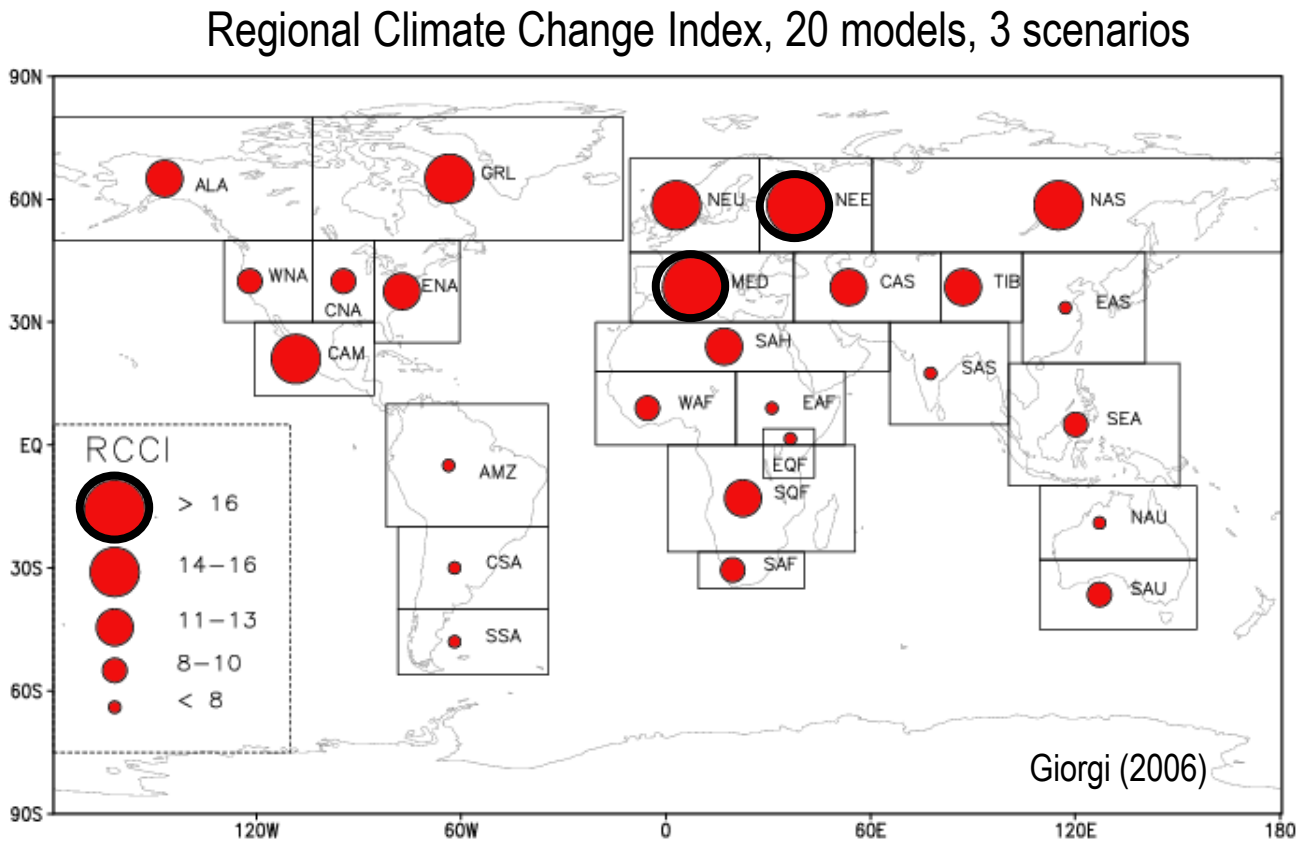
- *Gard, Sept. 2002: ~700 l/m²*
  20 deaths; 1 200 M€ de damages



- *Alger, nov. 2001: ~260 l/m²*
  886 deaths; 4 000 M€ de damages

… in a context of climate change

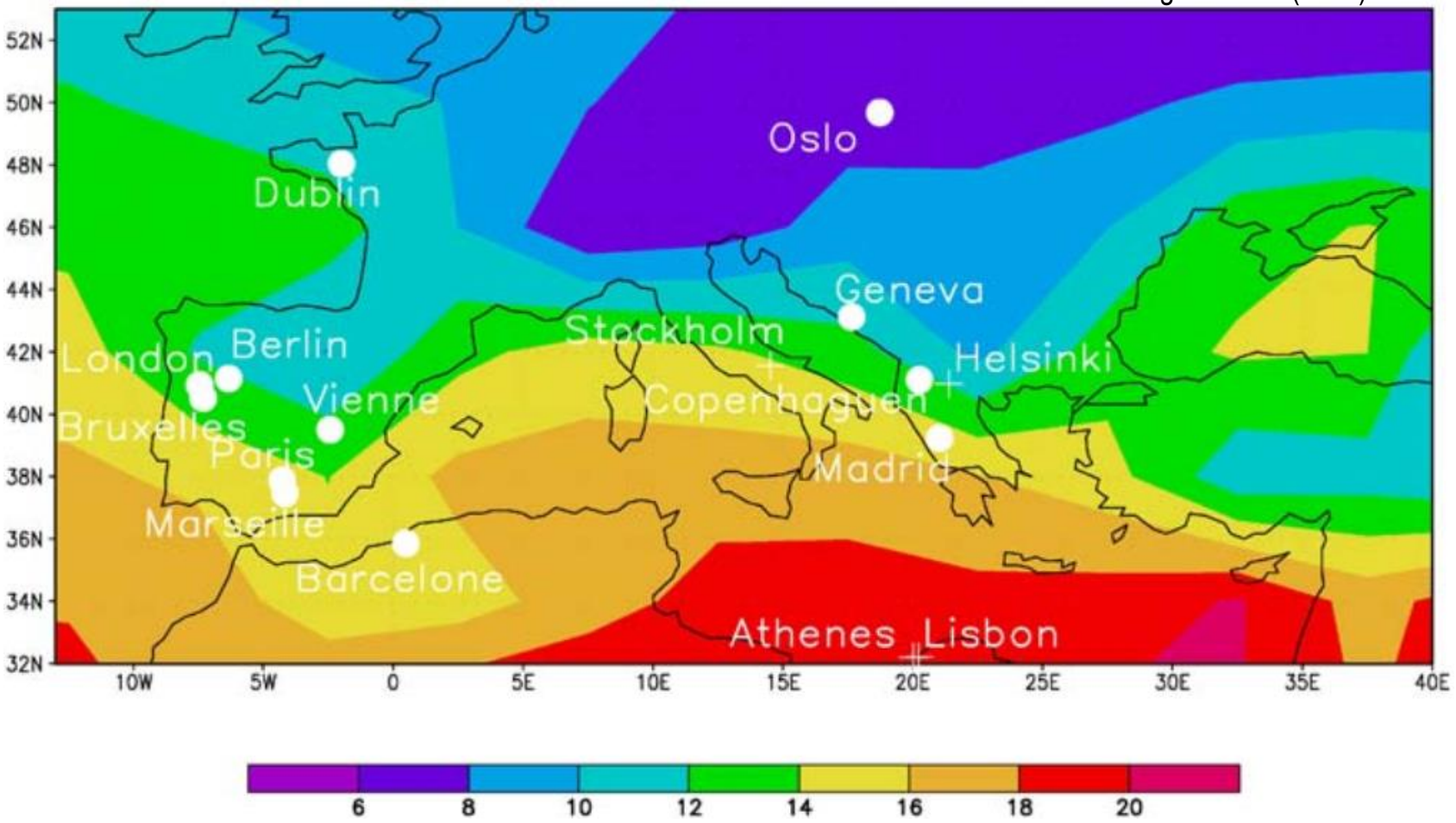
A "hot-spot" of climate change



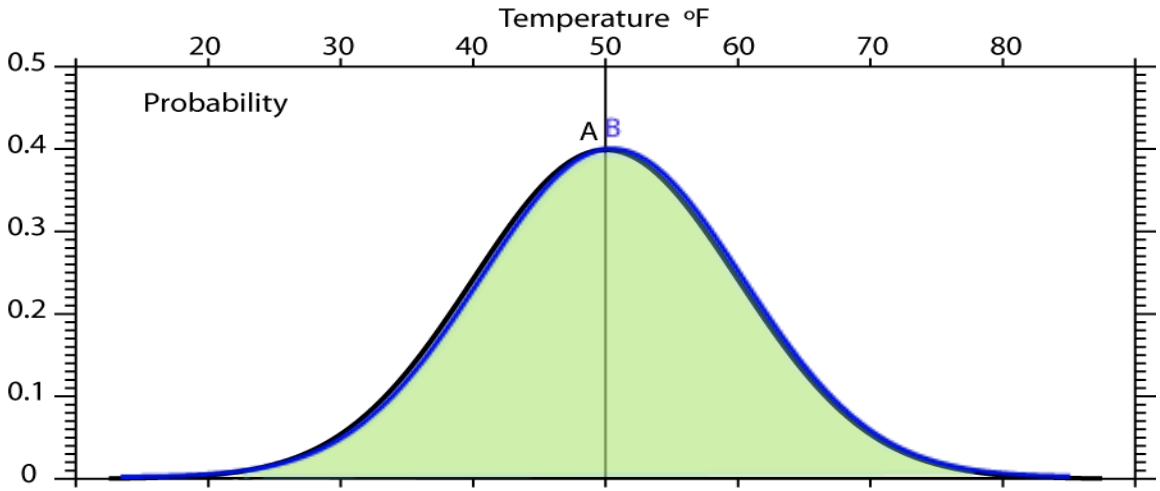
- *Strong regional response to climate change*
- *Projections: significant warming (between +1.4 et +5.8°C in 2100), decrease of the mean annual rainfall and increase of rainfall variability*

… in a context of climate change

Source: Hallegatte et al. (2007)



Reason for focus on extremes

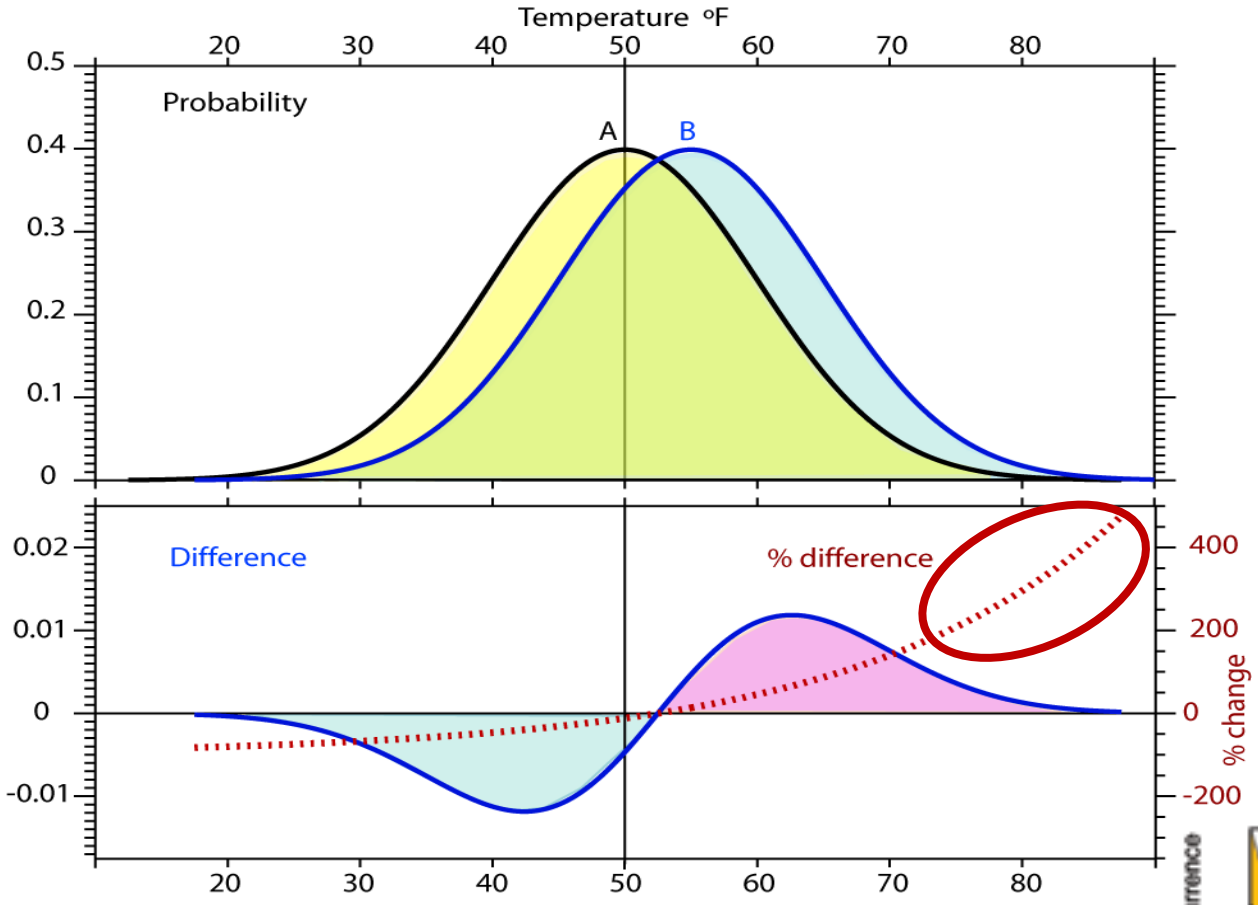


Shift in climate: from A to B

Mean A: 50°F, s.d. 10°F

Source: Trenberth

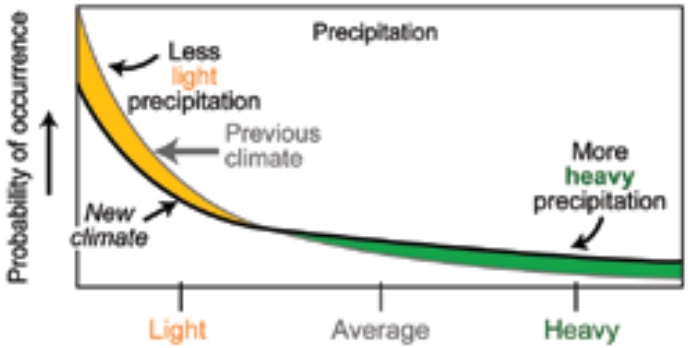
Reason for focus on extremes



Shift in climate: from A to B

Most of time the values are the same (green).

Biggest changes in extremes: >200%



Mean A: 50°F, s.d. 10°F

Mean B: 55°F, s.d. 10°F

Source: Trenberth

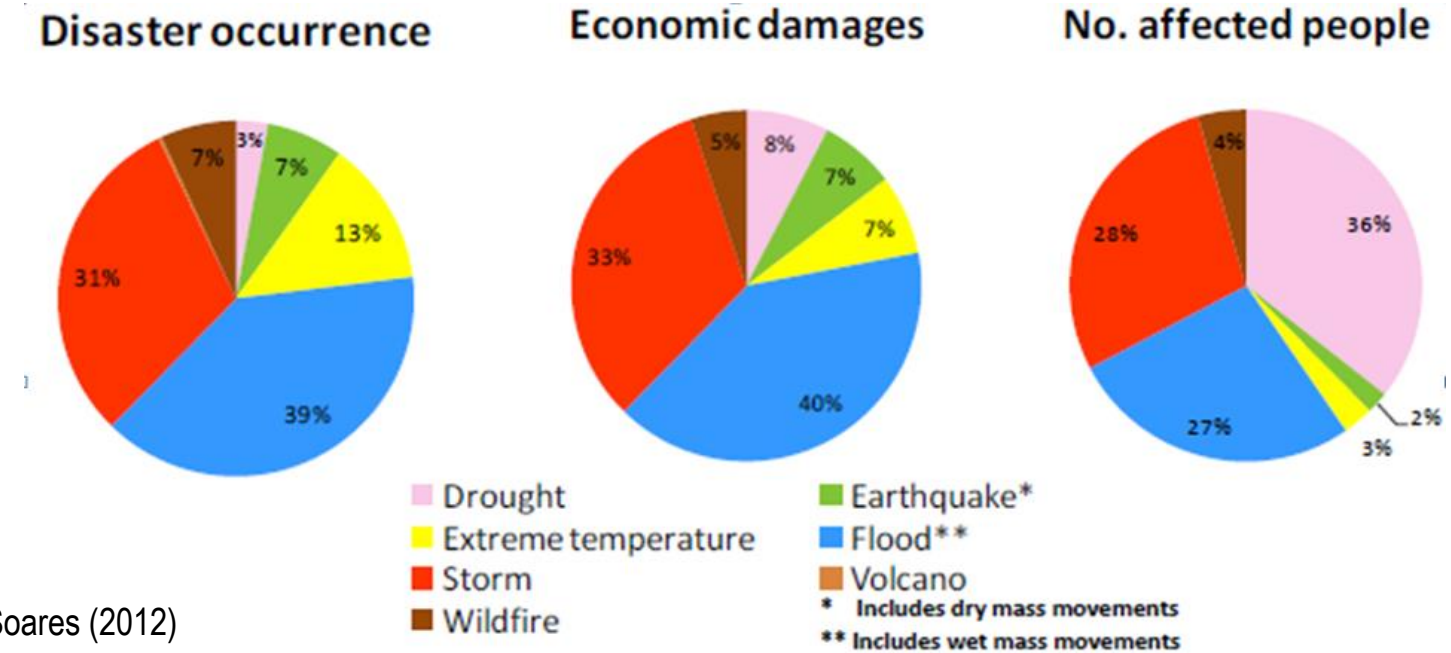
Reason for focus on extremes

Cost of droughts and heatwaves

- ► 2000-2006: 15% of the EU total area and 17% of the EU total population have suffered from the impacts of droughts
- ► Most severe event in 2003 with more than 30.000 deaths in Europe (caused by the heatwave)
- ► Total cost of drought over the past 30 years: above 100 billion €

Cost of floods

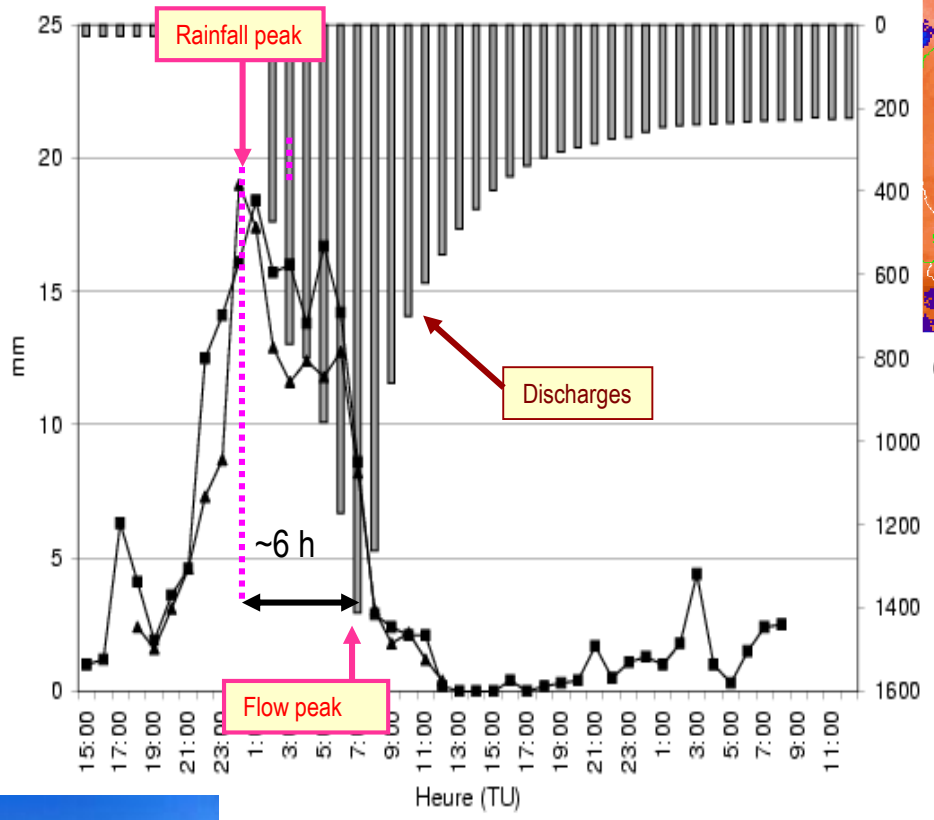
- ► 1998-2002: EU suffered over 100 major damaging floods, including catastrophic floods along the Danube and Elbe rivers in 2002.
- ► 1998-2004: floods caused some 700 fatalities, the displacement of about half a million people and at least € 25 billion in insured economic losses

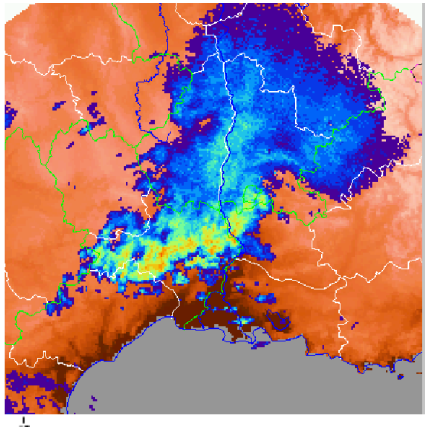


Source: Soares (2012)

Heavy precipitation and floods

Gardon d'Anduze Watershed (545 km^2)

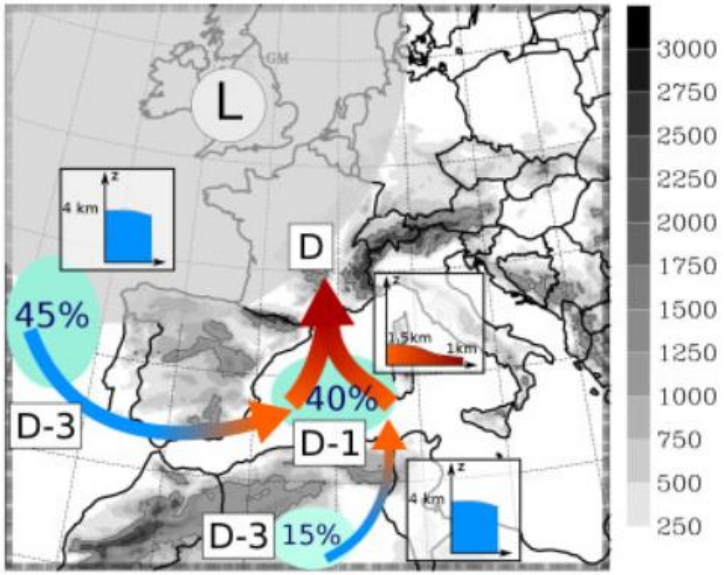


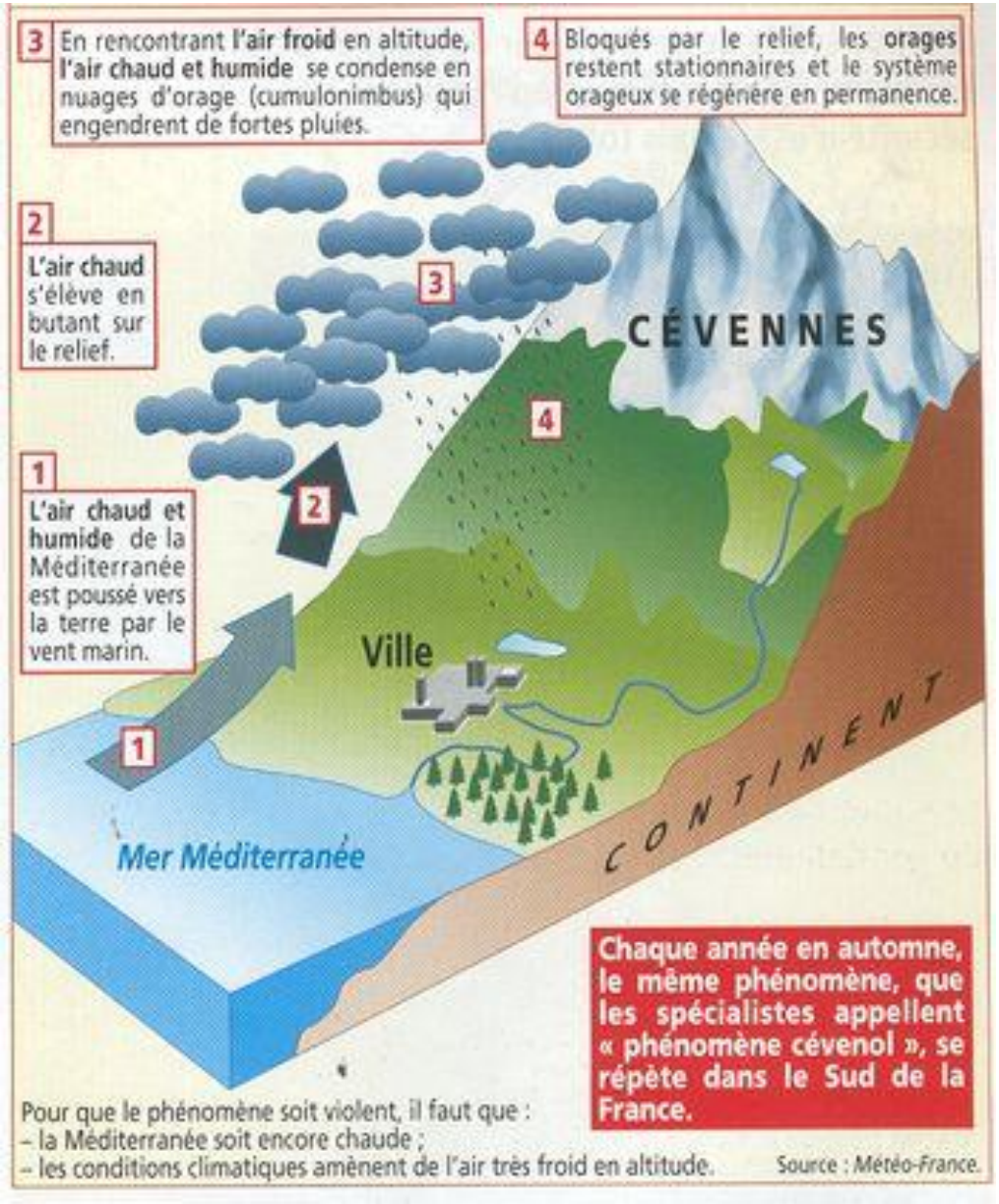


Source: Ducrocq

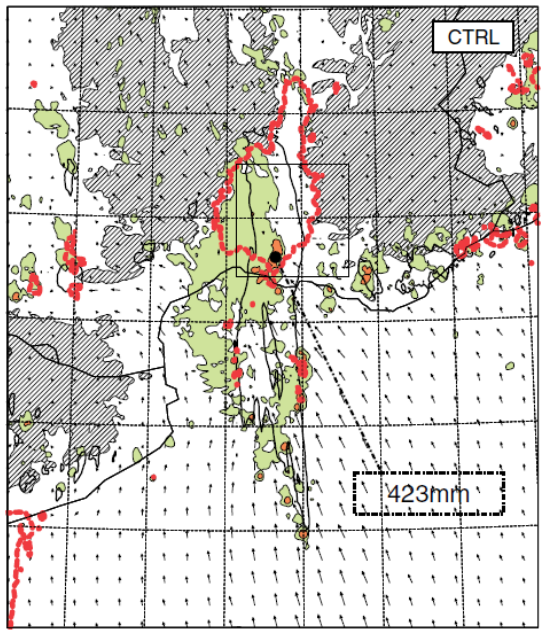
Heavy precipitation and floods

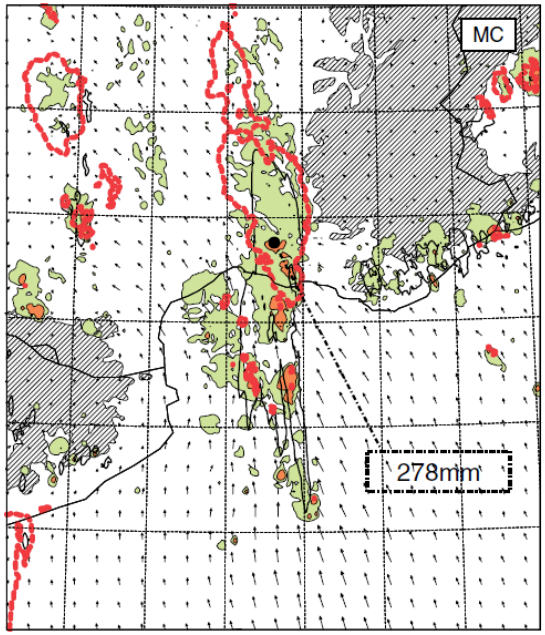
Source: Duffourg and Ducrocq (2013)

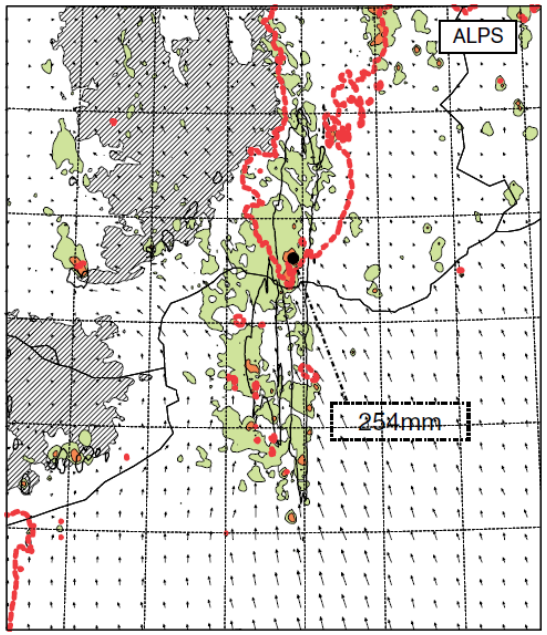


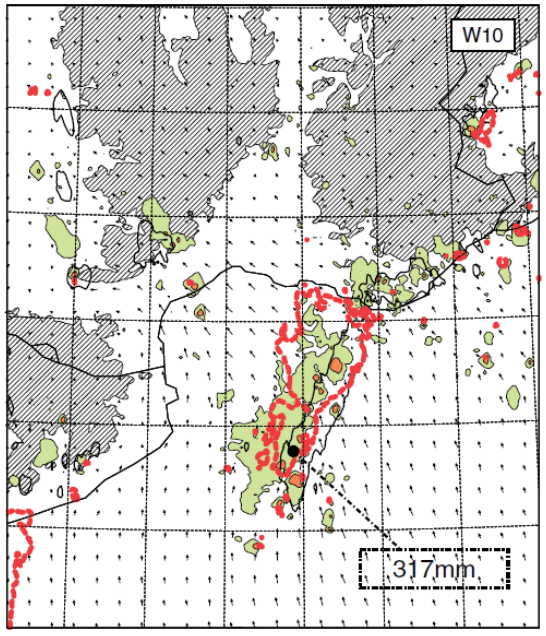


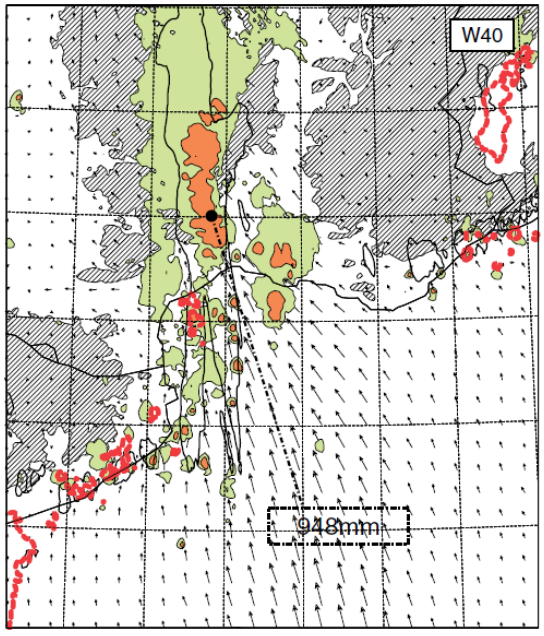
Heavy precipitation and floods







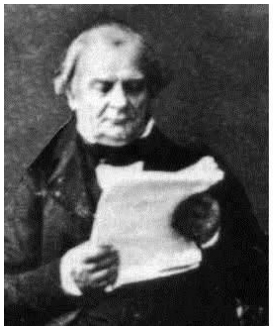




Source: Bresson et al. (2012)

Heavy precipitation and floods

Clausius-Clapeyron (CC) law tells us that the water holding capacity of the atmosphere goes up at about 7% per degree Celsius increase in temperature →Air holds more water vapor at higher temperature



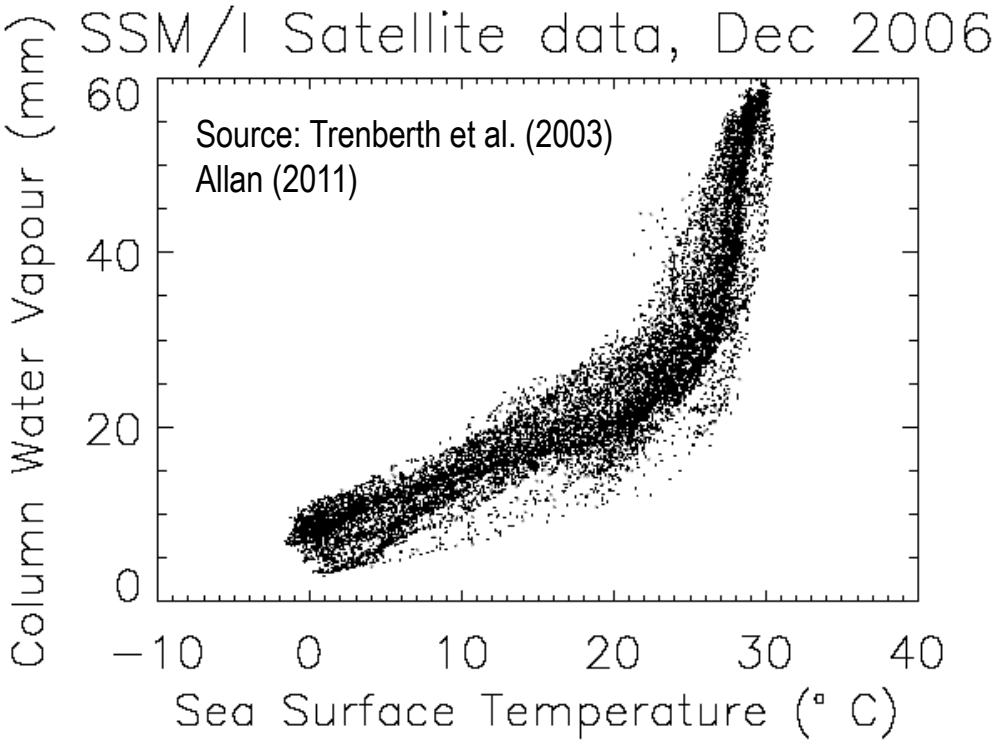
$$k = \left(1 - \frac{\delta}{\varrho}\right) \frac{dp}{dt} C.$$

E. Clapeyron (1834)

$$r = C \cdot (s - \sigma) \frac{dp}{dt}.$$

R. Clausius (1850)

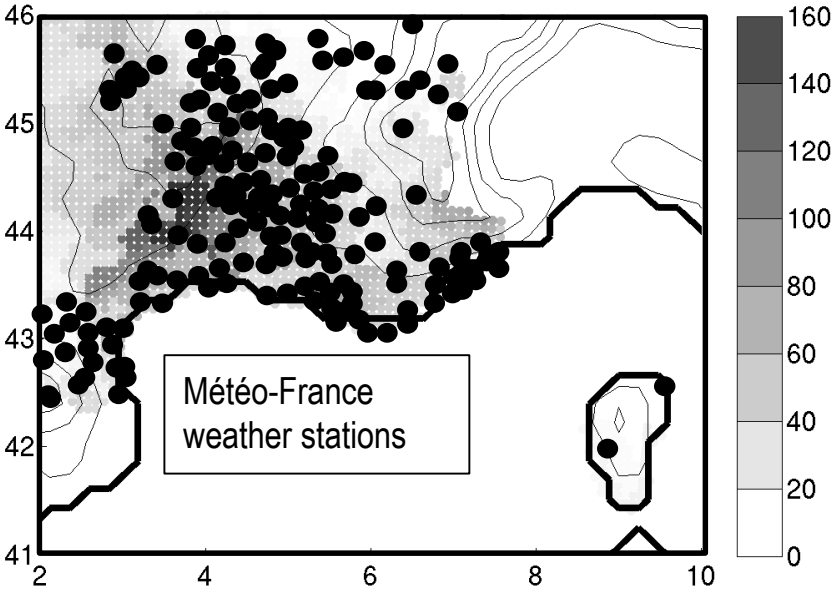
Observations show that this is happening at the surface and in lower atmosphere: 0.55°C since 1970 over global oceans and 4% more water vapor.

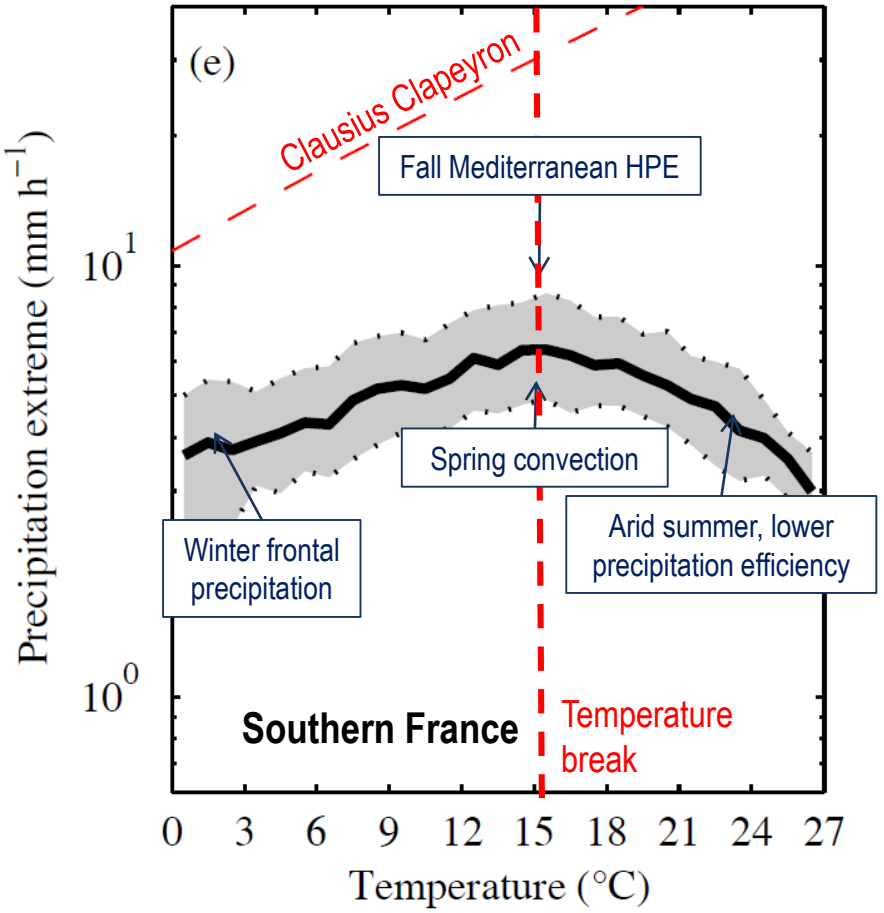


This means more moisture available for storms and an enhanced greenhouse effect

More intense precipitation expected in a warming climate !!!

Heavy precipitation and floods

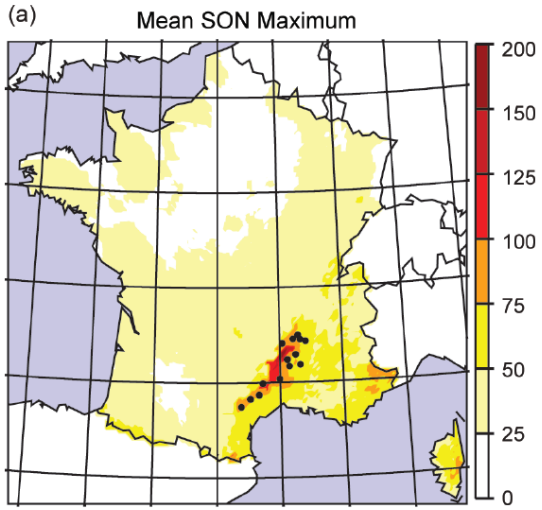


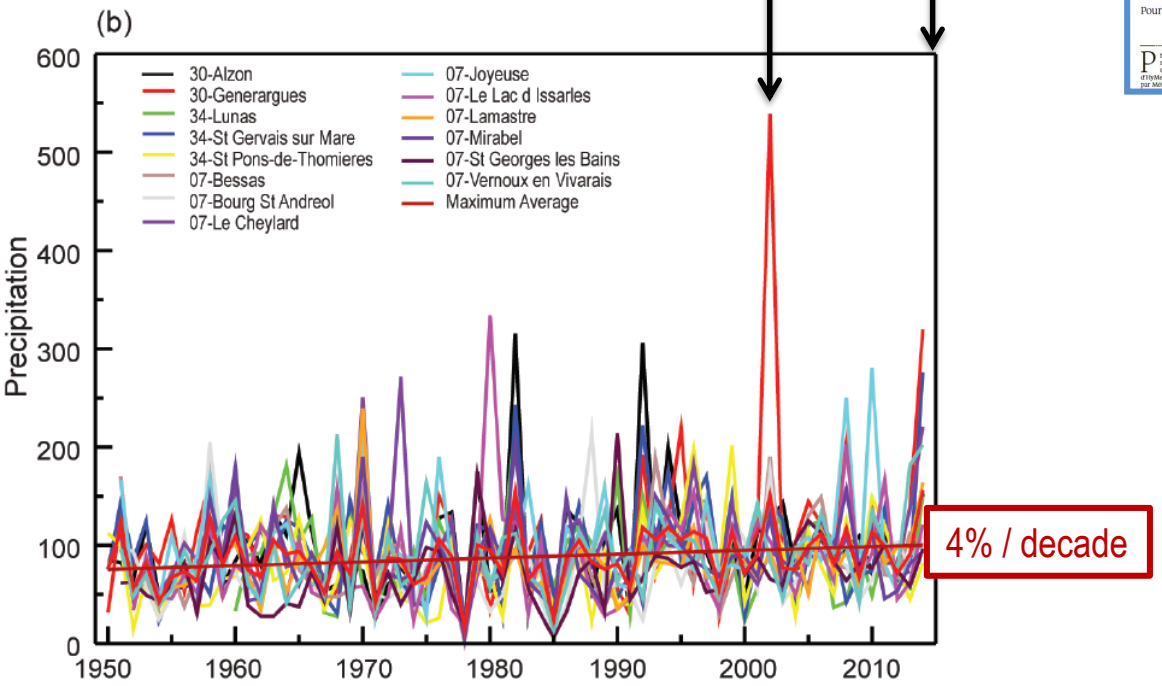


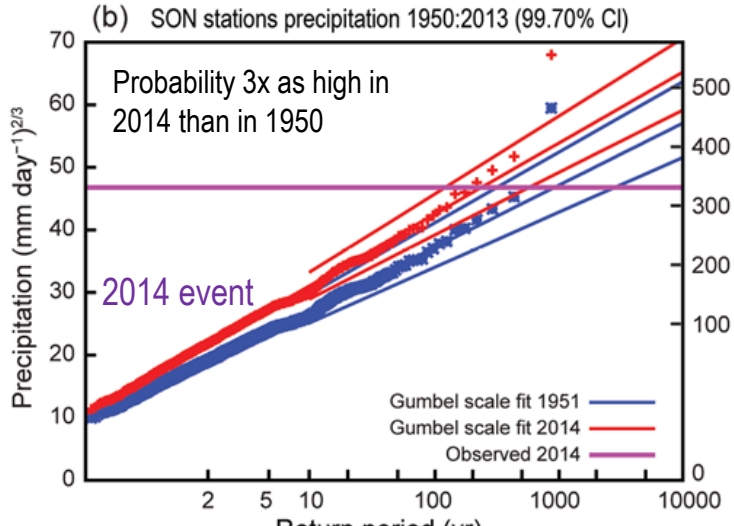
Source: Drobinski et al. (2016)

Heavy precipitation and floods

Vautard et al. (2014)

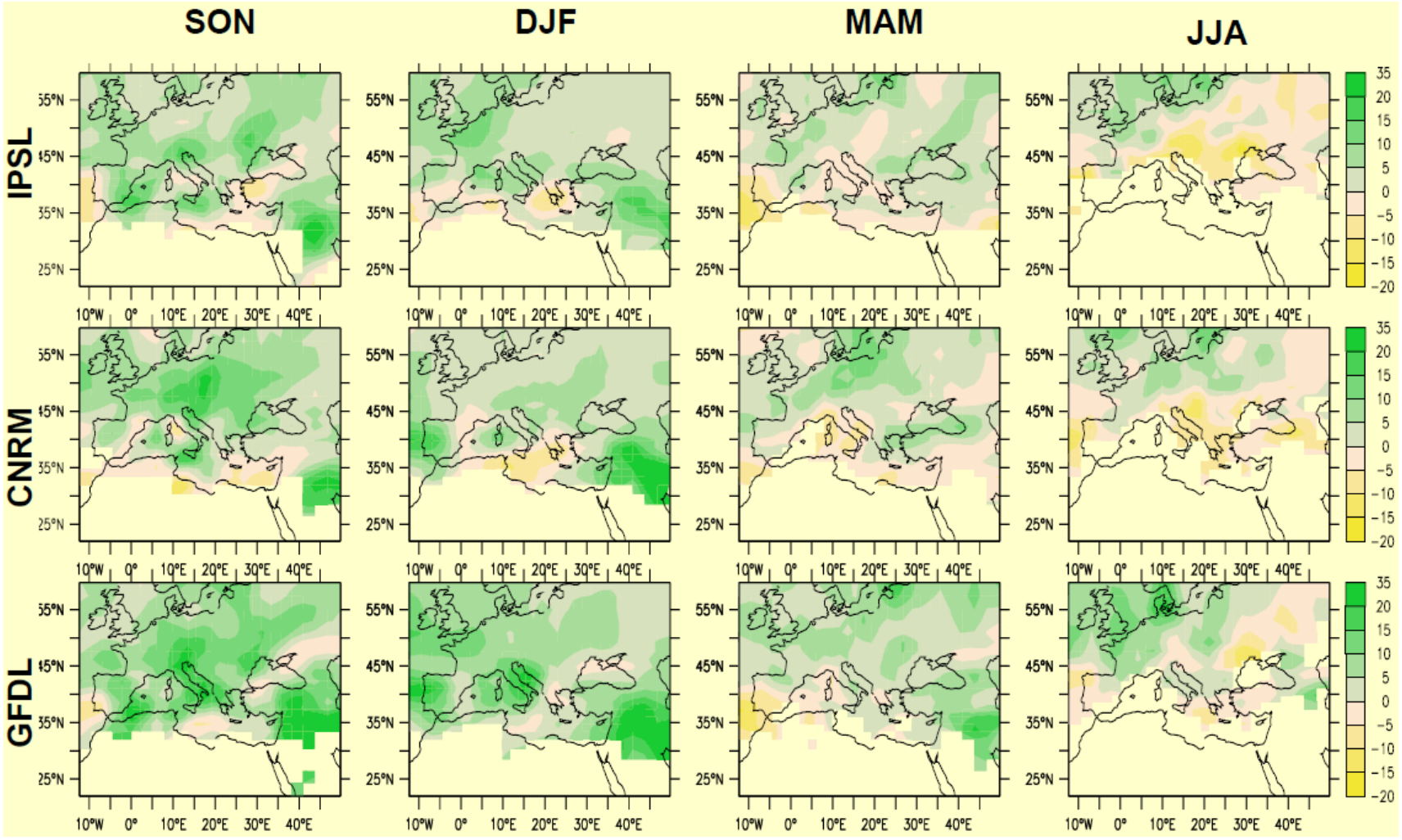






Heavy precipitation and floods

Extreme precipitation: 2070-2099

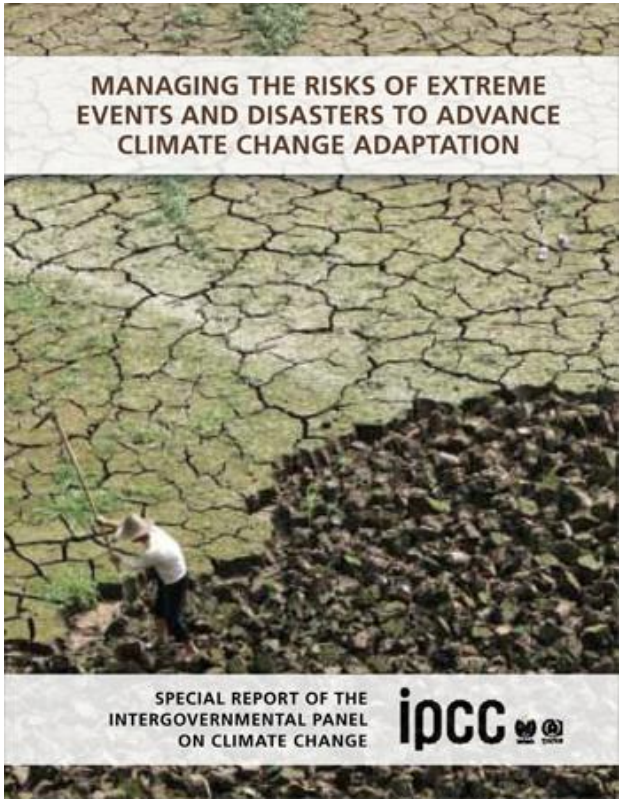


Source: Goubanova (2007)

Heavy precipitation and floods

IPCC SREX (2012) report on the increase (or not) of floods

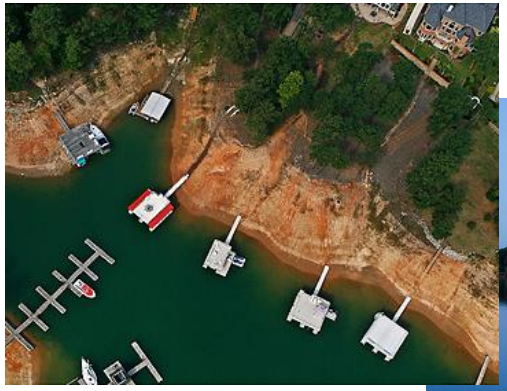
"… there is limited to medium evidence available to assess climate-driven observed changes in the magnitude and frequency of floods at regional scales because the available instrumental records of floods at gauge stations are limited in space and time, and because of confounding effects of changes in land use and engineering. Furthermore, there is low agreement in this evidence, and thus overall low confidence at the global scale regarding even the sign of these changes …"



Uncertainty driven by multiple indices, models, datasets, time periods …

Droughts and heatwaves

Reduced water levels/supply: public, industry and power generation



NY Times

Reduced agricultural, forestry and fisheries productivity

BBC

Increased livestock mortality rates

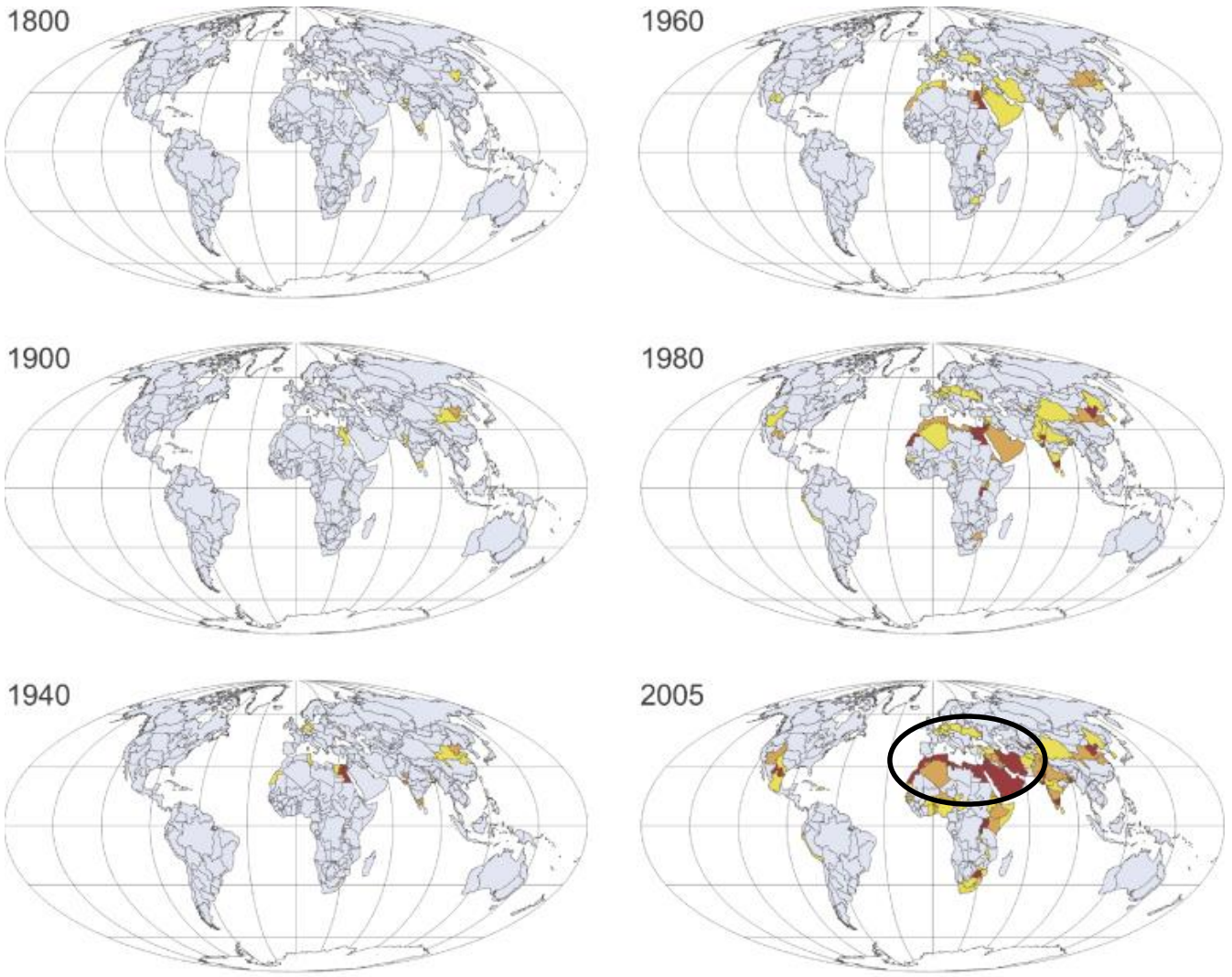
John Mccolgan/US Forest Service

Increased fire hazard/tree die off

Damage to wildlife habitat

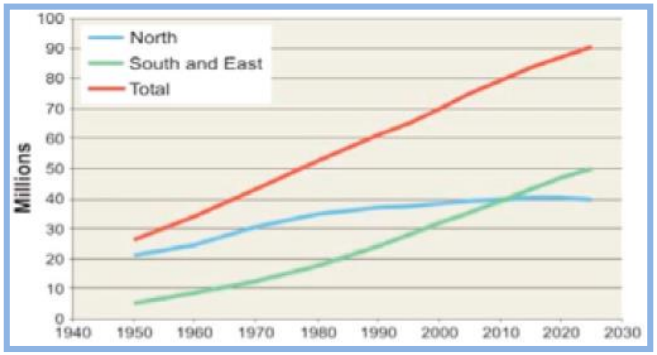
BBC

Droughts and heatwaves



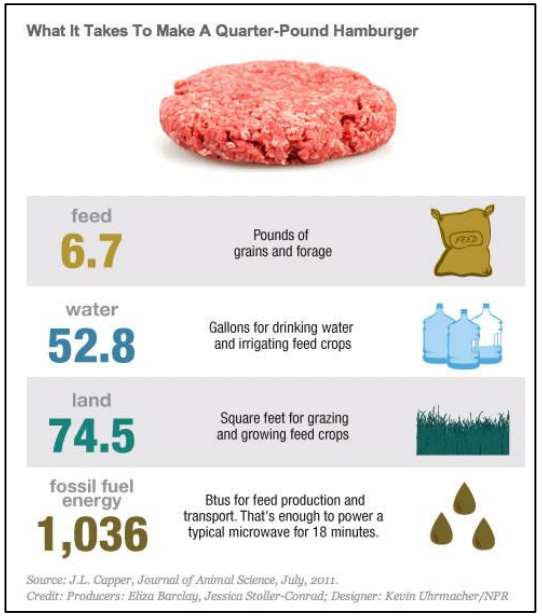
Source: Kummu et al. (2010)

Droughts and heatwaves

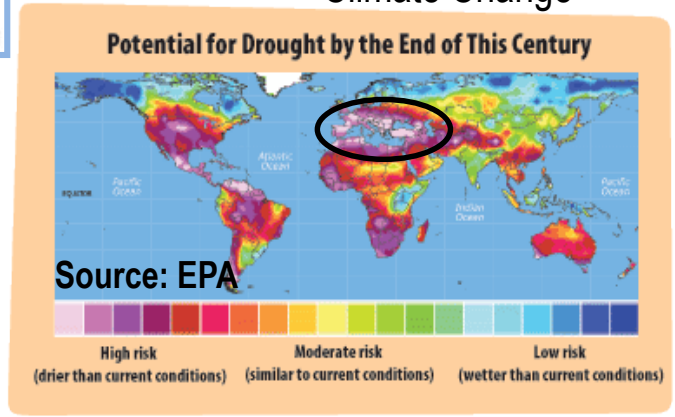


Population growth and changing demographics

Agricultural demand and changing diets

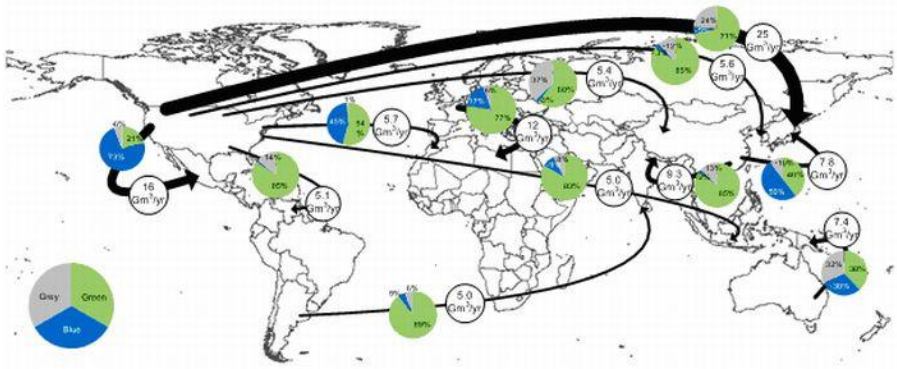


Climate Change



Unsustainable water use

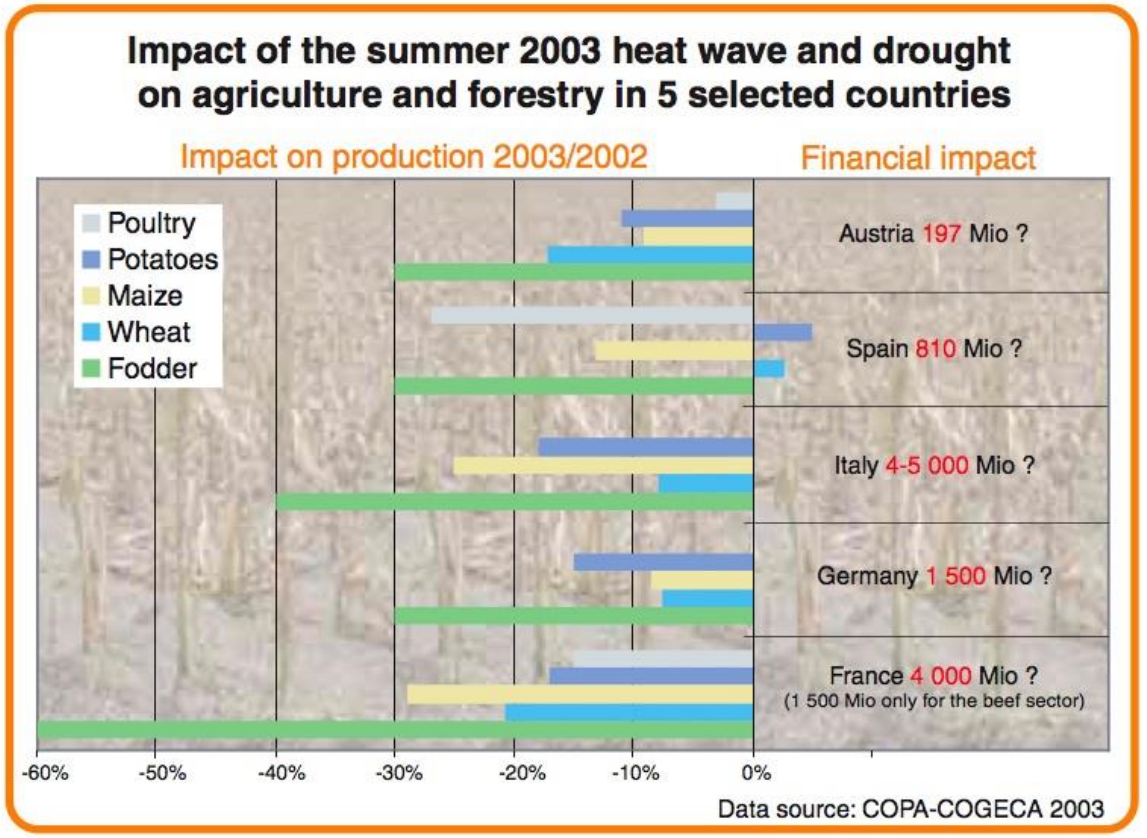
We live in a connected world



Droughts and heatwaves

Summer 2003 was the worst in 23 years for forest fires. 5.6% of forest area was lost.

Decrease of agricultural production



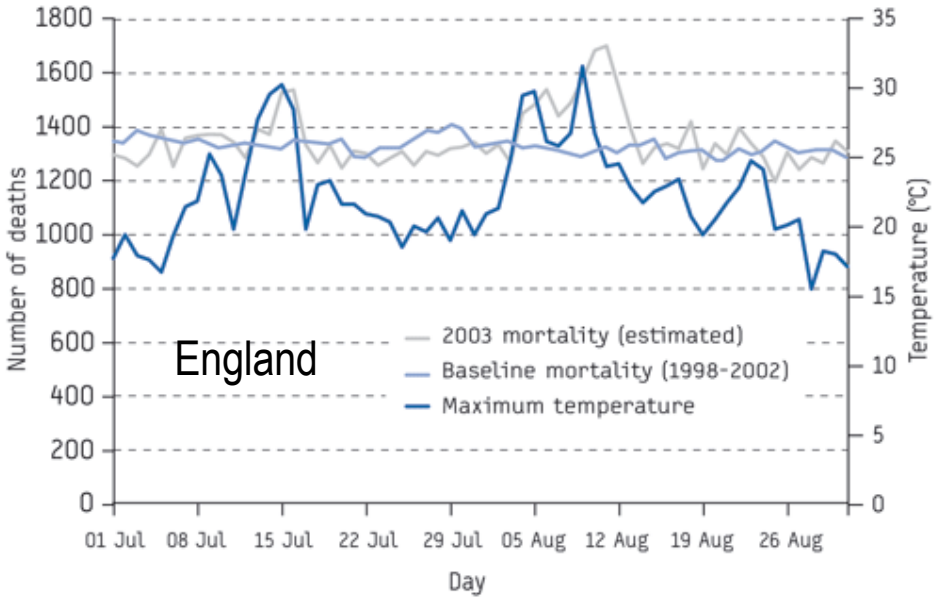
Droughts and heatwaves

Increased mortality

http://ec.europa.eu/healt/ph_information/dissemination/unexpected/unexpected_1_en.htm

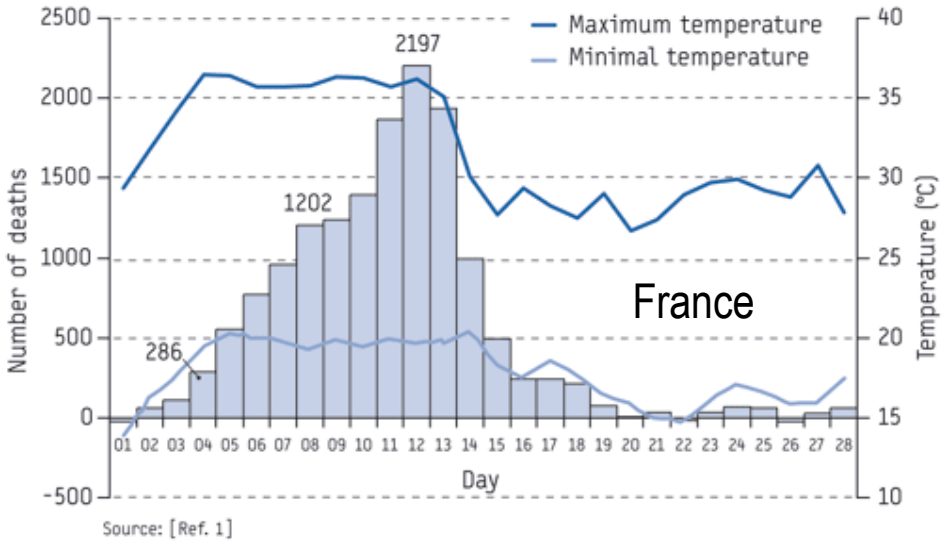
FIGURE 1

Maximum central England temperature and daily mortality, England and Wales, July and August 2003

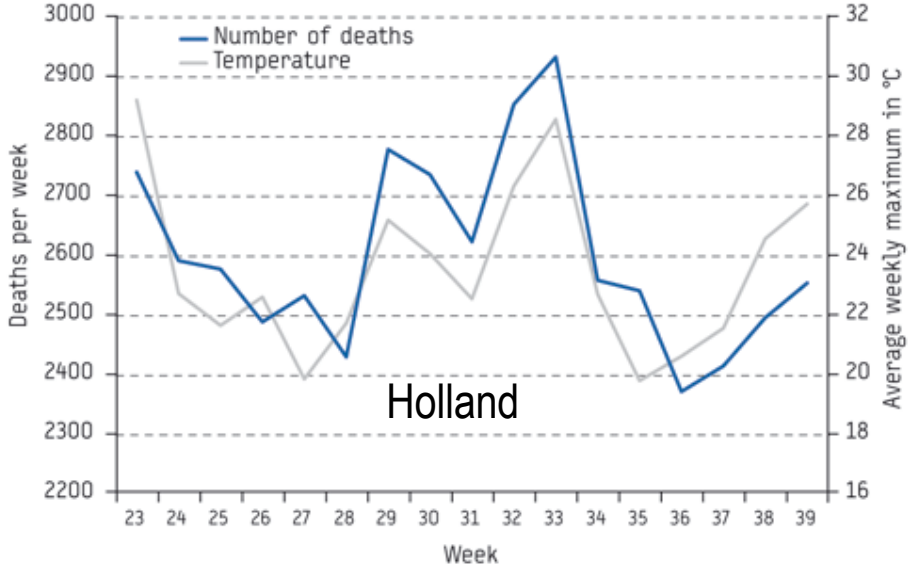


FIGURE

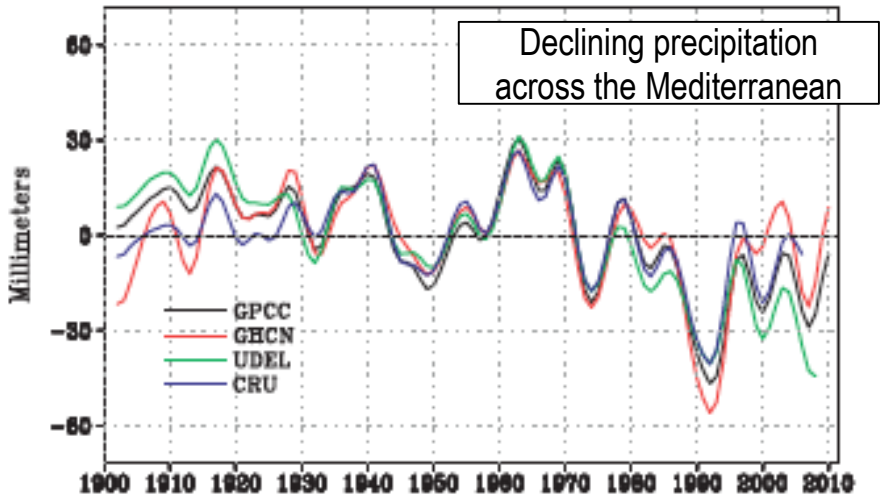
Daily excess of deaths during August 2003 and minimal and maximal daily temperatures, France

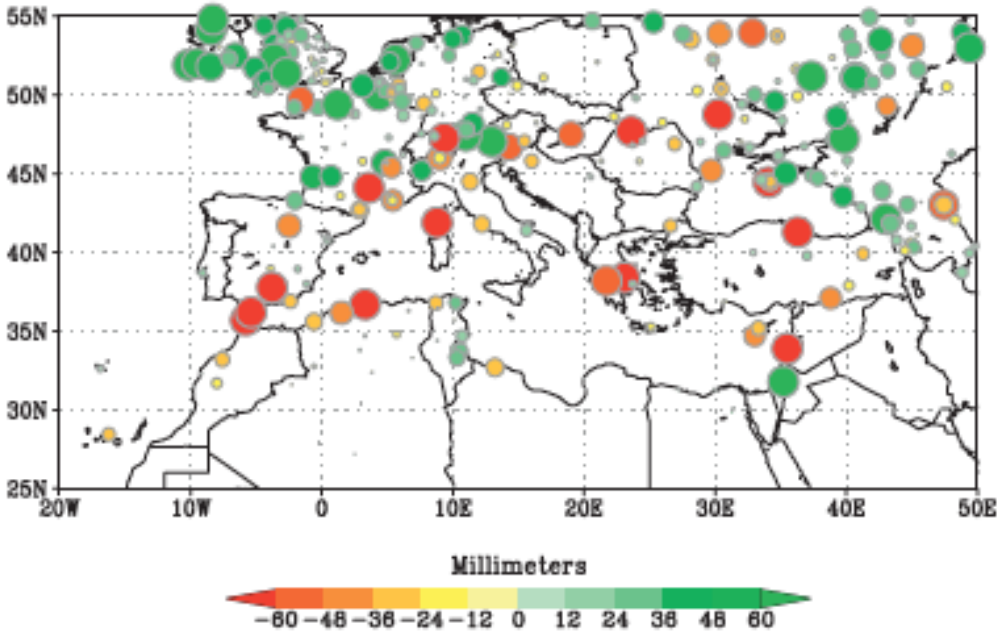


Mortality and average maximum temperature per week, The Netherlands, June-September 2003



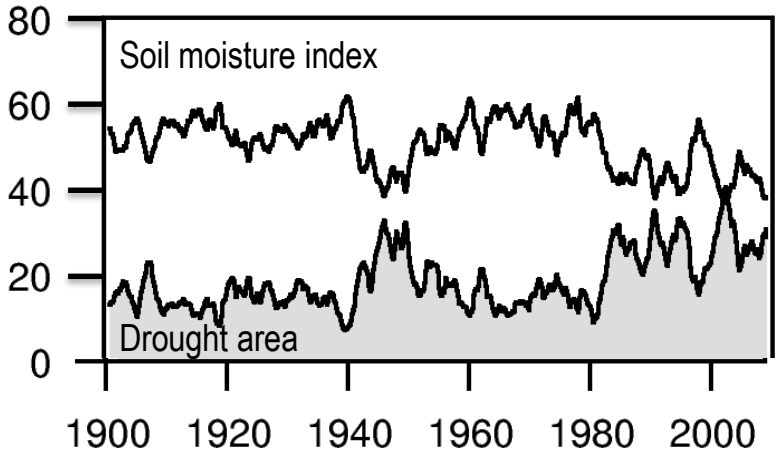
Droughts and heatwaves





Source: Hoerling et al. (2012)

Declining soil moisture in the Mediterranean

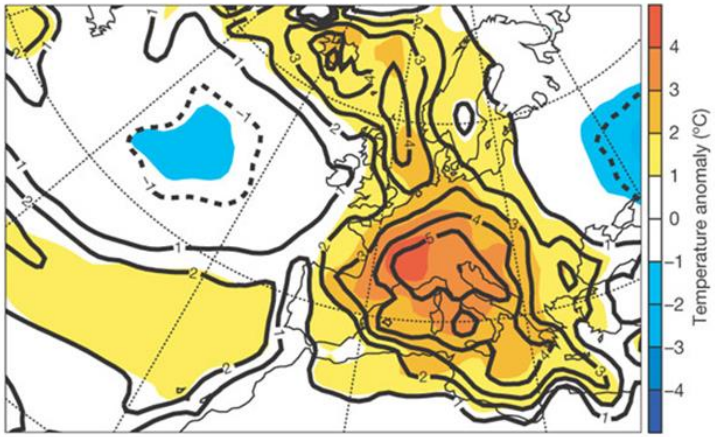


Soil moisture from observation-forced land surface model simulations

Source: Sheffield and Wood (2011)

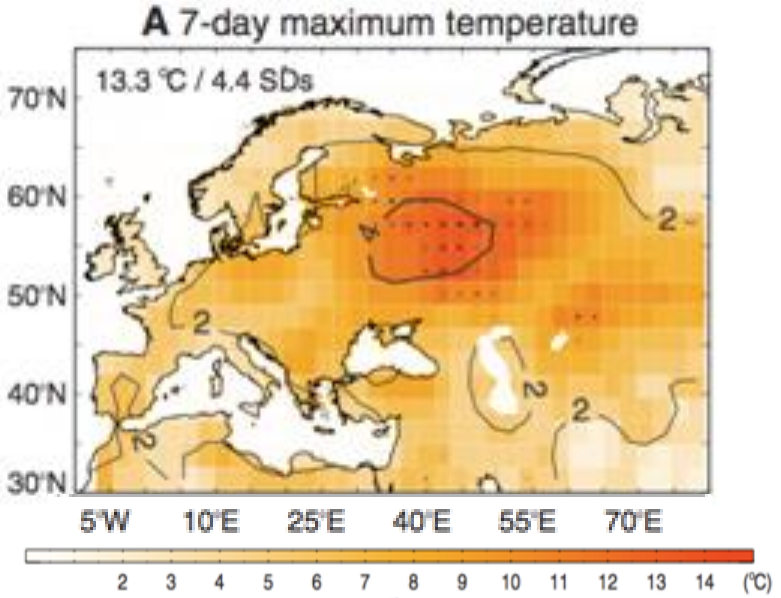
Droughts and heatwaves

The 2003 heatwave in Europe

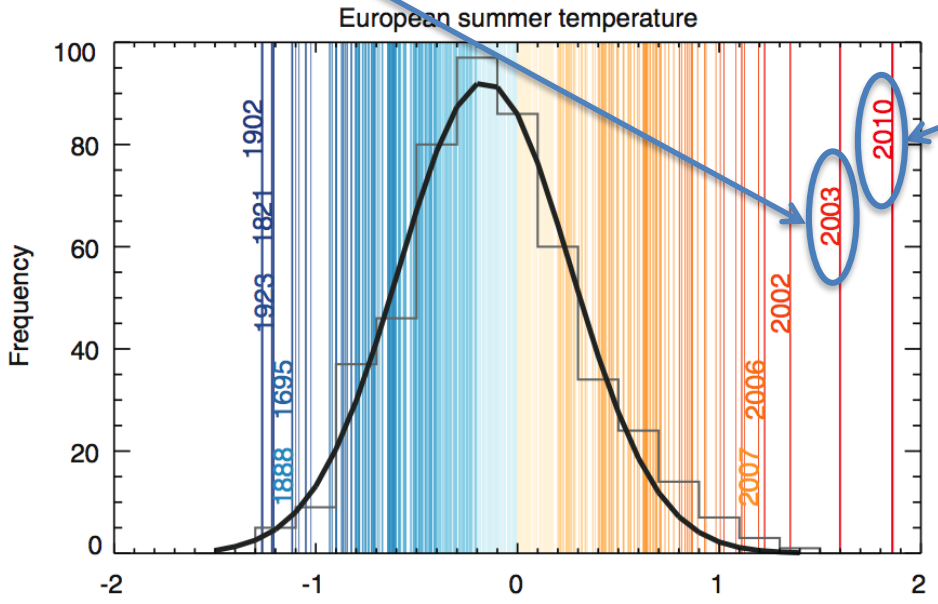


Source: Schär et al. (2004)

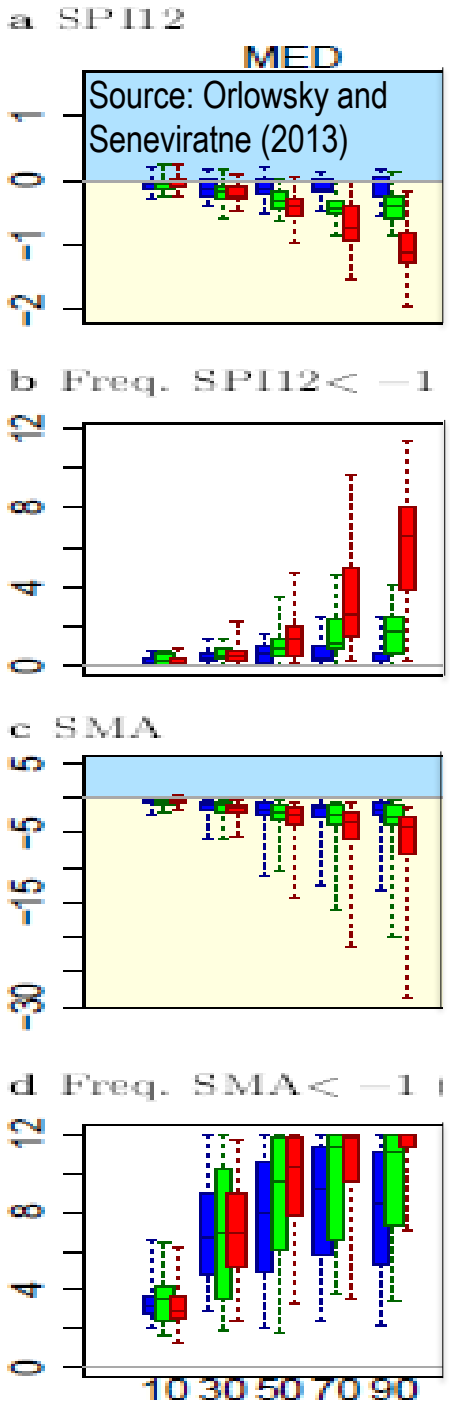
The 2010 heatwave in Russia

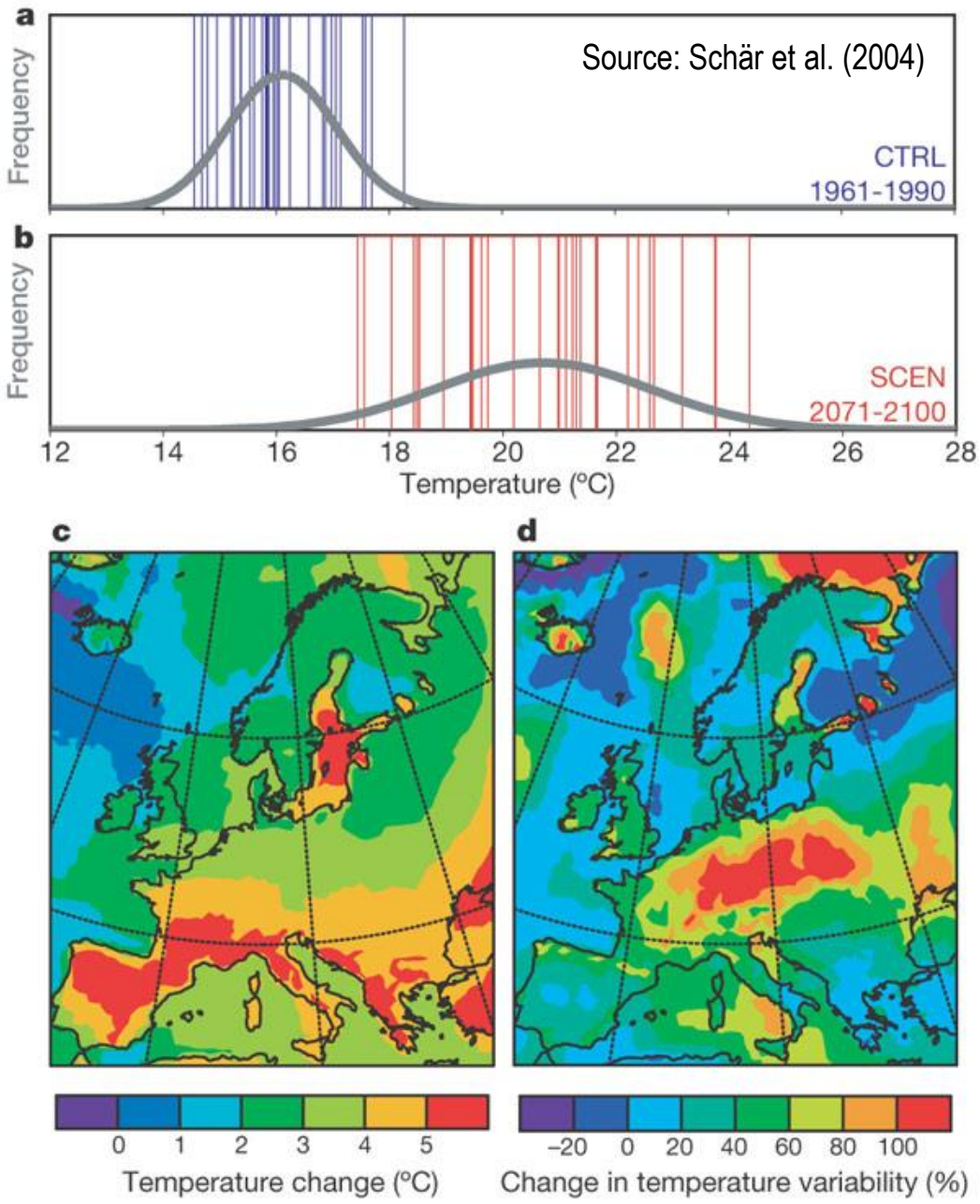


Source: Barriopedro et al. (2011)



Droughts and heatwaves





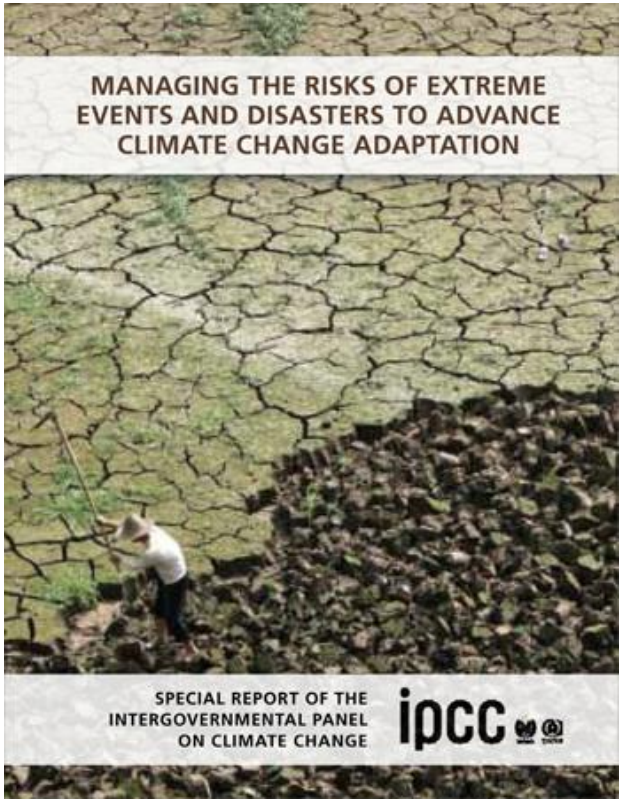
Droughts and heatwaves

IPCC SREX (2012) report on the increase (or not) of drought

"… there is medium confidence that since the 1950s some regions of the world have experienced ***trends toward more intense and longer droughts, in particular in southern Europe and West Africa****, but in some regions droughts have become less frequent, less intense, or shorter, for example, central North America and northwestern Australia.*

There is medium confidence that anthropogenic influence has contributed to some changes in the drought patterns observed in the second half of the 20th century, based on its attributed impact on precipitation and temperature changes.

However there is low confidence in the attribution of changes in droughts at the level of single regions due to inconsistent or insufficient evidence"



Uncertainty driven by multiple indices, models, datasets, time periods …

Some thoughts as a conclusion

* You'll see. If we raise the temperature very slowly, the frog does not notice anything

With these pessimistic conclusions…

… I thank you for your attention… Questions?